Elastic Convection in Vibrated Shear Thinning Fluids

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ずりに対し単調な粘性の減少を示す粘弾性物質、具体的には、超音波診断用に用いる流動ゲル、髭剃り用のジェル、或いは歯磨き粉で得られた新しいパターン形成について報告する。これらを台上で鉛直加振すると、外側から内側へ回り込む向きの２本の対流ロールが、方位対称性を破って発生する。加振の周波数が増加すると対流ロールの直径が大きく減少するが、加振振幅や粘性にはほぼ依存しない。

Recently, novel flow instabilities are found in complex fluids. For example, some complex fluids show shear banding state under constant shear, in which high shear rate region coexist with bands of low shear rate[2]. But these phenomena appear when the stress vs. shear rate relation reveals a nonmonotonic curve. On the other hand, there have been many studies on shear responses of complex fluids studied for steady shear. Although in some other systems, for example glanular materials, varieties of pattern formation including convective instability has been found by vertically oscillating them since a long time before[3], vibrational shear response to vibrational shear is not known very well yet.

In this report, we introduce an instability of non-Newtonian fluids with simple monotonic shear-thinning property. We use supersonic echo-gel as a testing material, which is applied on our skin when one has a supersonic medication. Putting the material on an alminium plate and vertically oscillating it, a convective pattern is formed as shown in Fig.1. We call it "Elastic Convection", since some stretching motion shown in Fig 1(c) occurs and seems to have important contribution to this motion. The same phenomenon is also observed using tooth paste or other material, so it is expected that this phenomenon has fairly universal aspect.

We checked how the mean angular velocity Ω changes by controlling the acceleration amplitude $\Gamma = A\omega^2/g$. The dependence of Ω on Γ is shown in Fig. 2, fitted as $(\Gamma - \Gamma_c)^{1.5}$ with Γ_c is the onset value of the acceleration, and only when $\Gamma > \Gamma_c$ the rolls can rotate. Checking the onset value Γ_c with various frequencies, we clarify the region where rotation can occur as

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shown in Fig. 3; the root mean square velocity $\overline{v} = \sqrt{\langle v^2 \rangle} = A\omega/\sqrt{2}$ need to be larger than $\overline{v_c} = 1.74$m/s for the rotation in the present setup.

The diameter of the rolls R decreases strongly with increasing the vibration frequency f. This dependence is approximated as $R \propto f^{-0.6(3)}$, and the diameter R is almost unchanged even when we change the parameters Γ or the viscosity.

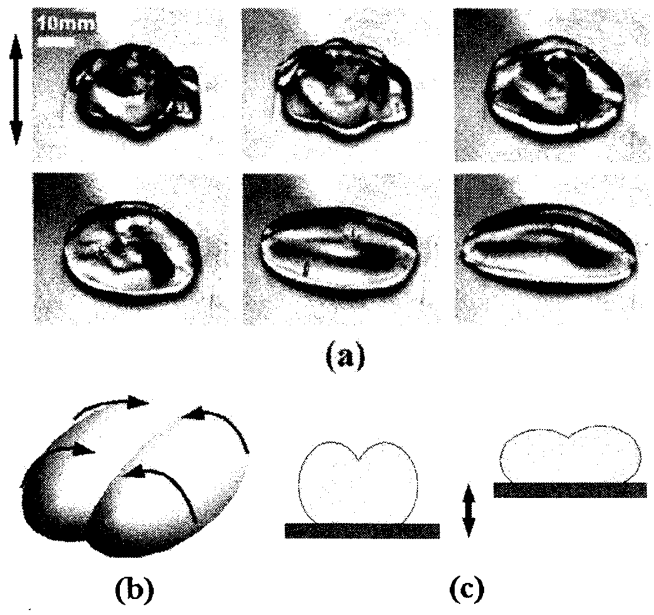

Figure 1: (a)Formation dynamics of the convective rolls.(b)Direction of the convection is shown by arrows. (c) The scheme of the cross section of the rolls.

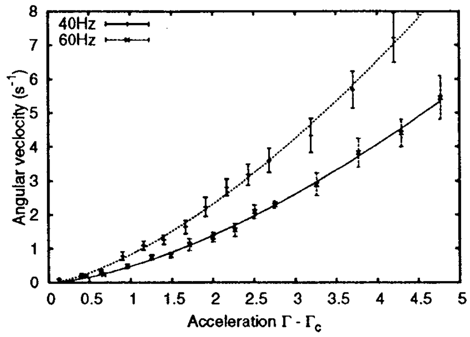

Figure 2: Mean angular velocity Ω dependence on the acceleration Γ.

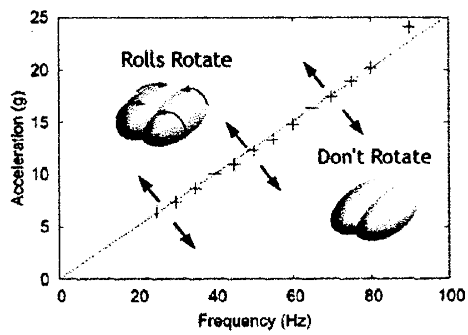

Figure 3: Dynamical phase diagram plotted as the function of Γ and ω.

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References

[1] Hayato Shiba, Yoshihiro Murayama, Qi Ouyang, and Masaki Sano, preprint (2005)

[2] S. M. Fielding and P. D. Olmsted, Phys. Rev. Lett. **92**, 084502 (2004)

[3] M. Faraday, Philos. Trans. R. Soc. London **121**, 299 (1831)